Mike Fellows: Weaving the Web of Mathematics and Adventure

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Abstract. This informal tribute in honor of Mike Fellows' 60th birthday is based on some personal recollections.

Mike Fellows is one of the founding fathers of parameterized complexity and among the few mathematicians who have really shaped theoretical computer science. This informal tribute in honor of his 60th birthday will mention a few of his lesser known deeds. It is based on personal recollections and will not even attempt to do justice to Mike's broad influence.

Michael Ralph Fellows was born near Los Angeles in California on 15th June, 1952. His family name derives from the Old Norse word *félagi*, mentioned on runic inscriptions in the meaning of comrade or weapon brother. As a young man he quite literally lived up to this nominative feature when he trained as a paratrooper in the Pararescue special forces outfit of the US Air Force. He soon turned his efforts to the more contemporary meaning of his name: "a fellow is often part of an elite group of learned people who work together as peers in the pursuit of knowledge or practice" [16]. However, also within the safe haven of academia Mike Fellows remains a fighter and a comrade in arms, fearless in his pursuit of knowledge and friendship alike.

Mike did his graduate studies in the 1980s at the University of California in San Diego, receiving a Master of Arts in Mathematics and a Ph.D. in Computer Science. In many Eastern religious traditions, one can attain Knowledge and Enlightenment only through a teacher already possessing these traits, with the Sanskrit word *parampara* denoting "the line of spiritual gurus in authentic succession of initiation; the chain of mystical power and authorized continuity, passed from guru to guru" [16]. A computer scientist will see here a recursive definition. While leaving the base case undefined, suffice it to say that Mike's ancestral line of supervisors contains some very famous names in mathematics, amongst them the Norwegians Sophus Lie, Axel Thue and Thoralf Skolem, via the graph theorist Øystein Ore, to the Americans Marshall Hall, Donald Knuth, and Mike's own supervisor Michael Fredman [13].

In the 1980s the pursuit of faster computing was tied to message-passing parallellism, which involved the mapping of a parallel computation to a parallel architecture and opened the way for some graph theory. Mike's thesis "Encoding graphs in graphs" was motivated by these issues. In general, you have a computation graph G and an architecture graph H and ask for a mapping of vertices $f : V(G) \to V(H)$ and a mapping of edges of G to paths in H so that $uv \in E(G)$

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is mapped to a path between $f(u)$ and $f(v)$. The goal is a load-balanced mapping with low dilation and contention. A mathematician at heart, Mike's main interest seems to have been the very structured cases. The above mapping is called a *covering* of H by G if the edges of G are mapped to edges of H, *i.e.* paths of length one, in such a way that edges incident with a vertex v in G are mapped bijectively onto the edges incident with $f(v)$ in H. For connected H the mapping is in this case perfectly load balanced and the related computational question is called the H-COVER problem: given a graph G, does there exist a covering of H by G? A paper by Mike with co-authors Abello and Stillwell [1] was the first to show existence of a graph H for which H-COVER is NP-complete: take H the graph on two adjacent vertices and a loop on each vertex. But there are also polynomial-time cases, e.g. only cycles of length a multiple of q will have a covering to the cycle of length q. For k-regular graphs we actually have a dichotomy: unless P=NP, H-cover for a k-regular graph H is polynomial-time solvable if and only if $k \leq 2$, see the survey [11]. However, a characterization of the graphs H defining a polynomial-time solvable H-COVER problem is still a wide open problem. What about taking H as a parameter? It is actually an open question if the parameterized viewpoint contributes anything in this case, since any graph H for which we know H-COVER to be FPT parameterized by H we also know it to be polynomial with H as part of the input.

The most famous open problem concerning graph coverings is probably Negami's conjecture from 1988 stating that a graph H has a planar cover (i.e. a finite planar graph G covering H) if and only if H embeds in the projective plane [14]. The 'if' direction is easy, and graphs embeddable in the projective plane are characterized by 32 connected forbidden minors. The main line of attack on the conjecture consider each of these forbidden minors to show that they do not have a planar cover. After many years of work a single graph remains, and the Negami conjecture has been reduced to showing that the graph $K_{1,2,2,2}$ does not have a planar cover, see the survey [12]. In an unpublished manuscript from 1988 [9] Mike made a related conjecture. An *emulation* is a mapping slightly less structured than a covering, requiring only that edges incident with each vertex v in G map surjectively (rather than requiring bijectivity) onto the edges incident with $f(v)$ in H. Mike showed that the property of having a planar emulator is preserved under taking minors and under $Y\Delta$-transformations and conjectured that a graph has a planar emulator if and only if it has a planar cover. This conjecture has remained firmly tied to Negami's conjecture over the years. However, in a surprising turn of events (called a "breakthrough" by one of the main experts on Negami's conjecture [12]) Rieck and Yamashita showed very recently [15] that $K_{4,5}$-$4K_2$ and $K_{1,2,2,2}$ *have* planar emulators, and since the first of these graphs has been shown *not* to have a planar covering, this disproves Mike's bold conjecture. Mike seems to have been the first to introduce the concept of emulators, which has later been studied under the name of role assignments with applications in the theory of social behavior [6]. In that case H models roles and their relationships in a society, G represents relations between a group of individuals, and the task is to assign roles to individuals so that each individual with a particular role has, among its neighbors, every role prescribed by H, and no other roles.

At a conference in New Zealand in 1990 Mike meets a local complexity theorist over a bottle of Villa Maria Cabernet Merlot and discover that they share many interests [5]. The resulting Downey-Fellows collaboration in parameterized complexity is still going strong and is our field's nearest equivalent of a Lennon-McCartney trademark. Being the new kid on the block, parameterized complexity has had to fight hard for its recognition, and Mike has been forced to put several of his talents into play, including his interests in theatre and education. In his Advice to Students he writes: "Story is central. Story is a bigger force than science. Everybody lives by stories. They are a primal force. In mathematics, we add formalism. We have equations that lead to solutions but story has its own logic. Find the story in what you are telling and presenting. This will help the listener meet you more than half-way" [10]. In every talk of Mike Fellows there is a clear storyline, and there are many of us who have been hooked on the parameterized viewpoint ever since first hearing about this suggested deal with the devil of intractability. In 1997 Mike spent a couple of weeks at the Department of Informatics at the University of Bergen in Norway and inspired us not only to do research in parameterized complexity, but also in education of children. Applying exercises taken from his book 'Computers Unplugged' (written with Tim Bell and Ian Witten) [2] we visited elementary schools to teach concepts like graph coloring. I vividly remember the local head teacher looking at the classroom of 11-year-olds merilly coloring the various graphs given to them on hand-outs and wondering aloud if this really had anything at all to do with mathematics or computers. Meanwhile, one of those kids produced a proof that a graph is 2-colorable if and only if it has no odd cycles.

When rumors started circulating in 1999 that Mike was getting married there were many of us who thought his days as a travelling mathematician were over. How wrong we were proven to be! Whereas the travelling mathematician par excellence is Paul Erdős, the travelling mathematical couple of the last decade is surely Mike and Fran. Frances Rosamond is Mike's life companion in all aspects, and shares his adventurous spirit and love for mathematics and education. Not only did they keep up the round-the-world weaving of the parameterized web by their own travelling, they also invited groups of young researchers for prolonged stays in their own home, and here I am stumped in my search for previous role models. In 2002 my then PhD student Christian Sloper was invited to work with Mike in Newcastle, Australia. Below is a report he recently sent me of his visit. Keep in mind that the Australian-based couple and their young visitors are a generation apart and that young mathematicians/computer scientists are not likely to prioritize household chores like cleaning, cooking or laundry.

> They are both very inclusive, not excluding anyone. I remember knocking on their door the first day, but nobody opened, so I just went in and found them in the living room. I was very well received and was immediately served some food. The next day Mike would teach me surfing, which for

> a bad swimmer like me was a scary experience. Not that he thought it a problem that I did not get to surf, he was rather more upset about how little I knew of world litterature. There was one bedroom upstairs, two bedrooms downstairs for the guests, and a storage room for surfboards and wetsuits. Either Mike or Fran would cook, and the meals were always matched with some wine.
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> While I was there we were only two guests, me and David, but at other times there were more. The furnishing of the house had a rather spartan aspect to it, with a flipchart being one of the essential items. Mike really likes to stand by a board and explain, "the man needs an audience" as Fran said. So he drew figures and explained, and was open to our comments. He was responsive to suggestions. I later came to see that he often gave our ideas a lot more praise than they really deserved. He was good at viewing the little things that we came up with in a positive light. In this sense he was very encouraging.
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> We lived there for a few weeks, but one day when they arrived back from one of their camping tours up and down the coast it became clear to all that it was time for me and David to move on. On these camping tours the surfboards naturally went along and also a flipchart, so Mike could explain his ideas to Fran. Surfing is supposedly best done in the morning before the sun has warmed the air over land and turned the wind, so Mike surfed mostly in the morning. But even in the middle of discussions he would follow the beaches by webcam and now and then suddenly disappear when the wind conditions improved.
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> After I moved out I met with Mike almost every day at the University. How much we actually accomplished together is less clear, as I did not produce massive amounts of articles down there, and most of them were with Elena. When we did things together with Mike, he was always very clear that anybody who had participated should be a co-author, so that's very good. To illustrate how inclusive they were I recall they incorporated in some discussions also the wife of a colleague since she apparently was good at problem-solving, in particular crossword puzzles. To me this seemed really more an inconvenience than anything else as she did not know any computer science. I don't think she made it as co-author, though. (*by C.Sloper, translated from Norwegian by the author*)

Many young researchers can testify to Mike and Fran's inclusiveness. On later visits to our by now burgeoning algorithms research group in Bergen, Mike has always been accompanied by Fran, and the two of them have kept up a schedule that would be unimaginable to most. Not only in the amount of travelling from place to place, but also for their mode of work, where they invite collaboration from anyone, and could end up with five research meetings on the same day, with different groups of people. Lucky are all the young people who have benefited from these opportunities to work with the leading figure in the field. At least for our research group this collaboration with Mike has been indispensable.

Here is another quote from Mike's Advice to Students: "Some problems have important applications, while others have the potential to build theory. Some people are natively problem solvers with sharp tools and others are theory builders with a big picture view, although probably all are a bit of both." Safe to say that Mike is a lot of both! He is never afraid of delving deeply into a technical reduction. A prime example is the problem of computing the cliquewidth of a graph, a parameter first introduced in 1993 [4], with virtually everyone realizing it must be NP-complete, but aach, nobody able to show it. Cliquewidth is a slippery fish. For all that anybody knows it may even be that removing a single vertex may drop its value by half. In 2006, in a technical tour-de-force, by forcing the optimal cliquewidth expressions of a class of graphs into a more compliant linear structure, Mike, Fran, Udi Rotics and Stefan Szeider managed to hold the cliquewidth fish long enough to make an NP-completeness reduction [8]. As regards Mike and theory building, history speaks for itself. Possibly the notion of kernels will turn out to be the most lasting. At least they are the simplest to explain. Every practitioner knows that confronted with a difficult problem instance you first do some easy pre-processing to reduce the instance down to its hard kernel. How can we model this for an NP-hard problem? Could we ask for a reduction of each instance to a smaller one in polynomial-time? Alas no, that would imply P=NP. But surely there must be cases where we can reduce at least the big instances? Yes, indeed, and we are forced to introduce a parameter k besides input size n to define "big" as $n > f(k)$ for some function $f()$. So the parameter appears naturally for two reasons, one practical, since for many applications the instances come equipped with a small parameter, and the other also practical, as the only way to account for the pre-processing that we do in any case. The notion of polynomial-sized kernels has the added benefit of tying into classical complexity theory [3], and today it is clear that parameterized complexity is no longer the new kid on the block.

Congratulations Mike, may you continue weaving the web of mathematics and adventure for many new generations of young scientists!

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